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ACCESS REGULATION AND CROSS-BORDER MERGERS: IS INTERNATIONAL COORDINATION BENEFICIAL?

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Access regulation and cross-border mergers: Is international coordination beneficial?

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Abstract

The international integration of regulated markets poses new challenges for regulatory policy. One question is the implications that the overall international regulatory regime will have for cross-border and/or domestic merger activity. In particular, do non-coordinated policies stimulate cross-border mergers that are overall inefficient, and is this then an argument for international coordination of such policies? The paper addresses this issue in a setting where firms must have access to a transportation network which is controlled by national regulators. The analysis reveals that while non-coordinated regulatory policies may induce cross-border mergers (by allowing the firms in question to play national regulators out against each other), this can nevertheless be overall welfare enhancing compared to market outcomes under coordinated regulation.

Keywords: Access regulation; Endogenous merger; Policy coordination

JEL Classification: L13; L41; L50

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1 Introduction

International integration of regulated markets poses new challenges for regulatory policy. Integrated markets are to a large extent regulated by national regulatory bodies that pursue policies aimed at furthering narrow national interests. Moreover, countries have often chosen different approaches to market and regulatory reform (as in several energy markets), which have raised concerns about the overall efficiency of the system, and in particular whether there is a need for improved coordination of national regulatory policies and institutions in these sectors.

One aspect that regulatory policies must deal with is the restructuring via mergers and acquisitions that has taken place partly as a consequence of deregulation and liberalisation. These developments have occurred both at a national level, in the form of domestic firms merging with or acquiring other domestic firms, and at an international level, where firms have merged with or acquired targets across national borders. For instance EDF-GDF, the former French energy monopolist, has acquired London Electricity, an important UK energy provider, and is planning expansion into other European national energy markets. In Scandinavia the Swedish company Vattenfall has expanded through mergers and acquisitions both nationally and to a significant extent in other Scandinavian countries, including Norway.

Firms may merge for a variety of reasons, including increased profit opportunities associated with synergy gains, improved market access and increased market power. In regulated industries, including gas and electricity, such profit opportunities are influenced by the regulatory regime. In particular, when firms in different countries merge, the consolidated enterprise will relate to national regulatory bodies in all the countries where it operates. This opens up the possibility for the firm of strategically exploiting non-coordinated behaviour on the part of these bodies, and to some extent pitting the bodies against each other. The profit opportunities associated with this strategic position may then be another motive for national firms to merge internationally. Cross-border mergers may thus in part be motivated precisely by a lack of international regulatory coordination.

The strategic position of multinationals in regulated industries poses challenges for regulatory policy and for international coordination of such policies. One possibly important aspect of this challenge is the implications that the overall international regulatory regime will have for cross-border and/or domestic merger activity. In particular, do non-

coordinated policies stimulate cross-border mergers that are overall inefficient, and is this then (another) argument for international coordination of such policies? In this paper we address precisely this issue.

An interesting finding is that the answer to the posed question may be negative; thus the analysis reveals that non-coordinated regulatory policies may induce mergers that are overall welfare enhancing compared to market outcomes under coordinated regulation. This finding thus points to the possibility that international coordination of regulatory policies may have detrimental effects for overall welfare.

To explain this result one may start from the observation that detrimental effects of international cooperation typically only arise in 'second-best' settings where regulators have a limited set of instruments and means to influence economic agents' decisions.[1] We consider a setting where regulators (realistically) have limited means to influence firms' decisions with respect to mergers and acquisitions, and in particular cannot commit to policies that leave firms with pure profits (rents) that may motivate such decisions. We assume that regulators in line with welfare considerations will, for a given market structure, pursue policies that benefit consumers by leaving as little rent as possible in regulated firms. But the opportunities to extract such rents are different under cooperative compared to non-cooperative regulatory regimes. In the non-cooperative case a multinational firm may to some extent pit a national regulator against foreign regulators by a (more or less implicit) threat of moving nationally desirable activities abroad. Such a credible threat may 'soften' the national regulator and force her to leave more rents to the firm. In equilibrium the multinational enterprise can thus, due to the strategic position facilitated by its opportunities to move activities internationally, obtain a rent; a mobility rent. It would not be possible to obtain this rent if policies were fully coordinated, so that all national regulators related to the firm on a cooperative basis. We point out that this rent; the mobility rent associated with multinational operations under non-cooperative regulation, can be a decisive motive for cross-border mergers. Moreover, such mergers may be socially desirable. Hence it follows that non-cooperative regulation may be overall beneficial compared to a fully cooperative regulatory regime.

[1] This is of course a quite general point. In the theory of optimal time consistent taxation, it is well known that various impediments to taxation can be a blessing in disguise, since the implicit commitment to lower taxation can bring forth investments in capital or education, or the like. See, for example, Konrad and Lommerud (2001), Konrad (2001) and Andersson and Konrad (2003).

Our focus on and analysis of the links between regulatory regimes and merger activity is to our best knowledge new. The regulation literature has analysed various aspects of equilibrium policies when firms are subject to multiple regulatory bodies. This literature includes Baron (1985), Laffont and Tirole (1991), Stole (1992), Martimort (1996a,b), Bond and Gresik (1996), and Calzolari (2001, 2004). There are also some parallel issues in the literature on taxation of multinational enterprises and strategic tax policy (see, e.g., Markusen (1995), Haaparanta (1996) and Olsen and Osmundsen (2001)). Neither of these literatures has considered the links to merger activity. In our model regulators oversee market access (via a network), and their task is to regulate the price of this access. The received literature on access pricing (see, e.g., Armstrong (2002) for an overview) does not make the link to merger activity either. Bassanini and Poyet (2005) study non-coordinated international regulation of network access, but assume a competitive industry. Nese and Straume (2005) analyse how national regulators can use access prices (or other tax instruments) strategically to shift rents among different parts of a successive international oligopoly. Again, merger is not an issue.

There are close structural similarities between the model presented here and the relatively large literature on mergers in vertical industrial structures. Examples of this line of work include Horn and Wolinsky (1988), Inderst and Wey (2003), Lommerud, Straume and Sørgard (2005, 2006), O'Brien and Shaffer (2005) and Symeonidis (2005). The production firms in the model will then be 'downstream' firms that supply to a market, while the regulators will be 'upstream' input suppliers (supplying 'access'). The present model adds to this literature on several counts. Firstly, the upstream agents are here regulators that have a broader objective function than profit-maximising input suppliers. Secondly, many of the mentioned articles only study the consequences of downstream mergers – while we look at the possibility of different types of downstream mergers and how the anticipation of such mergers influence upstream cooperation. Thirdly, we allow for the upstream agent to use a two-part tariff. Two-part tariffs are considered also in Ziss (1995) and Milliou and Petrakis (2005), but they only look at the profitability of *upstream* mergers.

There are also links to the literature on strategic trade policy, as the regulated access price in our model can be manipulated to help a domestic firm to gain international market share. The paper in this tradition that lies closest to us is Huck and Konrad (2004). This paper finds that active strategic trade policy can lead firms to choose national over international mergers because this triggers higher per-unit subsidies of production. There

are many differences between this work and our own model. We allow the regulator to use a two-part regulatory scheme. This takes away the attraction of national mergers: Even though they could spur increased strategic per-unit subsidies (lower per-unit access prices), this benefit will be confiscated through an increase in the lump-sum tax element. Moreover, a central focus in our paper is how possible merger choices influences the benefits from international policy coordination, something which is not an issue in Huck and Konrad.

The remainder of this paper is organised as follows. The model is presented in Section 2. Section 3 studies the baseline case of cooperative regulation and merger incentives in this case. A corresponding analysis of non-cooperative regulation is found in Section 4. Section 5 uses an endogenous merger model to predict what mergers will take place in the equilibrium market structure under different assumptions about the regulatory regime. Section 6 is devoted to social welfare issues. After asking what types of mergers are socially desirable under cooperative or non-cooperative regulation, we turn to the question if international policy cooperation would be beneficial. Section 7 concludes the paper.

2 Model

Consider an industry with initially four single-plant firms located in two countries; firms (plants) 1 and 2 are located in country A, whereas firms (plants) 3 and 4 are located in country B.[2] The firms produce a homogenous good (e.g., electricity or natural gas) which is exported to a third country. Third-market exports require access to a transportation network, where the access price (assumed to be a two-part tariff) is regulated by the respective national governments. We further assume that the firms compete á la Cournot in the export market.

Third-market demand for the good is given by an inverse demand function

$$p = a - b\sum_{i=1}^{4} q_i, \tag{1}$$

where p is the market-clearing price and q_i is quantity supplied from plant i. The variable cost of production at each plant is given by the convex cost function $C(q_i)$. For simplicity,

[2] Regarding notation, we use the indices j and i for countries and plants, respectively, while the set of plants located in country j is given by N_j. We will also intermittently use subscript $-j$ to denote the other country than j. Finally, where appropriate, we use superscripts d and c for market structures with domestic and cross-border mergers, respectively.

we let this function take on a simple quadratic form: $C(q_i) = \frac{c}{2}q_i^2$. The firms must also incur a firm-specific fixed cost K. In the decentralised market structure, with no mergers, profits of firm i, located in country j, are then given by

$$\pi_i = (p - w_j)\, q_i - C(q_i) - K - T_j, \quad i \in N_j, \tag{2}$$

where w_j and T_j constitute the two-part tariff for access to the transportation network in country j.

National regulators are concerned about maximising national welfare, which – in the absence of domestic consumers – is assumed to be given by a weighted sum of public revenue and private profits. In the decentralised market structure, national welfare in country j is given by

$$W_j = 2T_j + w_j \sum_{i \in N_j} q_i + \alpha \sum_{i \in N_j} \pi_i, \quad \alpha < 1. \tag{3}$$

The assumption that α is strictly less than one implies that the regulator will extract all private profits if she is costlessly able to do so. The above specification of welfare also implicitly rests on the assumption that there are no costs associated with the operation of the transportation network (i.e., transportation costs are zero).[3]

We consider the following game:

Stage 0: The firms decide whether to merge domestically or cross-border, if at all.

Stage 1: The national regulators set, cooperatively or non-cooperatively, access prices, given by (w_j, T_j).

Stage 2: The firms choose outputs simultaneously and non-cooperatively.

Placing the merger decisions at the outset of the game reflects the fact that mergers are indeed long-term decisions with a considerable degree of commitment involved.

For clarity of analysis, we restrict attention to two-firm mergers. In order to illustrate the main workings of the model, we start out by characterising the equilibria in all symmetrical market structures under different regulatory regimes. We then proceed to make predictions about the equilibrium market structure of the full game.

[3] Positive transportation costs can easily be introduced, but offer no additional insight to our analysis.

3 Cooperative regulation

As a benchmark for comparison, we start out by considering the case where access regulation is harmonised across borders. In the *decentralised market structure*, profit maximising output quantities are given by

$$q_{i\in N_j} = \frac{a\,(b+c) - (3b+c)\,w_j + 2bw_{-j}}{(5b+c)\,(b+c)}. \tag{4}$$

Maximisation of global welfare implies that marginal access prices must satisfy the first-order conditions

$$\frac{\partial\,(W_A + W_B)}{\partial w_j} = 0, \tag{5}$$

while the fixed fees must be set so that the participation constraints are satisfied:

$$\pi_i \geq 0. \tag{6}$$

Solving (5) and (6), assuming that the participation constraints hold with equality, and taking into account that the choice of w_j affects the optimal choice of T_j, we derive the optimal two-part tariffs:

$$w_j = \frac{3ab}{8b+c}, \tag{7}$$

$$T_j = \frac{(2b+c)\,a^2}{2\,(8b+c)^2} - K. \tag{8}$$

We observe that optimal access pricing involves setting a marginal access price in excess of marginal transportation costs, i.e., $w_j > 0$. This is done to correct for the negative competition externality in the product market. By cooperative regulation, the cartel output – which maximises joint profits – can be implemented. Private profits can then be fully extracted through the fixed fee, T_j, leaving the firms with zero profits in equilibrium.

3.1 Mergers

Focusing on two-firm mergers, we consider the cases where the firms in the industry merge either domestically or cross-border, implying that the number of firms is reduced from 4 to 2. We assume that a merger entails a cost synergy, which takes the form of fixed-cost savings,[4] and we also allow for the possibility that the size of these fixed-cost savings

[4] The main mechanisms of the model, and thus our main results, does not particularly depend on the source of merger synergies. Fixed cost savings are thus chosen for analytical simplicity.

depends on whether the merger is domestic or cross-border. More specifically, we assume that cost savings in a domestic and cross-border merger, respectively, are $\theta_d K$ and $\theta_c K$, where $\theta_d, \theta_c \in (0,1)$.

In the case of *domestic* mergers, profits for the merged firms are given by

$$\pi_{1+2} = (p - w_A)(q_1 + q_2) - C(q_1) - C(q_2) - (2 - \theta_d)K - T_A, \tag{9}$$

$$\pi_{3+4} = (p - w_B)(q_3 + q_4) - C(q_3) - C(q_4) - (2 - \theta_d)K - T_B, \tag{10}$$

from which we can derive optimal outputs in the Cournot game:

$$q^d_{i\in N_j} = \frac{a(2b + c) - w_j(4b + c) + 2bw_{-j}}{(2b + c)(6b + c)}. \tag{11}$$

In the case of *cross-border* mergers, on the other hand, profits in one of the two possible ownership structures are given by

$$\pi_{1+3} = (p - w_A)q_1 + (p - w_B)q_3 - C(q_1) - C(q_3) - (2 - \theta_c)K - T_A - T_B, \tag{12}$$

$$\pi_{2+4} = (p - w_A)q_2 + (p - w_B)q_4 - C(q_2) - C(q_4) - (2 - \theta_c)K - T_A - T_B. \tag{13}$$

Profit-maximising outputs are found to be

$$q^c_{i\in N_j} = \frac{ac - w_j(3b + c) + 3bw_{-j}}{c(6b + c)}. \tag{14}$$

When analysing optimal access regulation we make the assumption that, in the case of cross-border mergers, profits are divided equally between share-holders in the two countries.[5] With cross-border harmonisation of access regulation, the regulators are always able to implement the full cartel output and extract all profits in equilibrium. The marginal access price is equal regardless of the type of merger, and given by

$$w^d_j = w^c_j = \frac{2ba}{8b + c}. \tag{15}$$

Comparing (7) and (15), we observe that a more concentrated market structure implies a marginal access price closer to marginal transportation costs, as we would expect. The fixed fee, on the other hand, depends on the size of merger synergies:

$$T^d_j = \frac{(4b + c)a^2}{(8b + c)^2} - (2 - \theta_d), \tag{16}$$

$$T^c_j = \frac{1}{2}\left\{\frac{(4b + c)a^2}{(8b + c)^2} - (2 - \theta_c)\right\}. \tag{17}$$

[5] In other words, half of the total profits generated in an internationally merged firm enters the objective function of a domestic regulator. It should be stressed, though, that the main thrust of the analysis does not depend on a particular sharing rule.

4 Non-cooperative regulation

Now we consider the case where national regulators set access prices simultaneously and non-cooperatively. We start out by analysing the regulatory game in the *decentralised* market structure.

Equilibrium access prices must satisfy

$$\frac{\partial W_j}{\partial w_j} = 0, \tag{18}$$

and

$$\pi_i \geq 0. \tag{19}$$

Using (4), equilibrium access prices are given by

$$w_j = \frac{ab\,(c-b)}{(c+7b)\,(2b+c)}, \tag{20}$$

$$T_j = \frac{(3b+c)^2\,a^2}{2\,(2b+c)\,(c+7b)^2} - K. \tag{21}$$

In the absence of international coordination, national regulators must now balance two opposing incentives in framing the optimal regulatory policies. One the one hand, national regulators have incentives to use the marginal access price to correct for a negative externality between domestic competitors, moving the market equilibrium closer to the cartel outcome. One the other hand, there is also an incentive to use the marginal access price as a strategic trade policy instrument. By lowering w_j from the cooperative equilibrium level, the regulator in country j can ensure – all else equal – that a larger share of the export market is served by the firms located in j. Since outputs are strategic substitutes in the product market game, this is a profitable deviation.[6] Consequently, the equilibrium level of w_j is lower when access pricing is not internationally coordinated.[7] The relative strengths of these opposing incentives are determined by the degree of convexity in production costs, measured by the parameter c. Strategic trade policy is more effective when c is low. Thus, a lower c increases rent-shifting incentives and leads to a lower equilibrium value of w_j. From (20) we see that marginal access prices will be set below marginal transportation costs in equilibrium (i.e., $w_j < 0$) if $c < b$.

[6] See, e.g., Brander and Spencer (1985).

[7] This is easily confirmed by a comparison of (7) and (20).

Domestic mergers

Solving (18) and (19) by using (11), equilibrium access pricing when firms merge domestically is given by

$$w_j^d = \frac{-4b^2 a}{10bc + 20b^2 + c^2}, \tag{22}$$

$$T_j^d = \frac{(4b+c)^3 a^2}{(10bc + 20b^2 + c^2)^2} - (2 - \theta_d) K. \tag{23}$$

Regulators are still able to extract all private profits.

The previously discussed negative externality on domestic competitors is now fully internalised by the firms themselves through mergers. Thus, when the market structure is characterised by national monopolies, only rent-shifting incentives matter for the choice of marginal access prices in the non-cooperative policy game. Consequently, domestic mergers lead to lower equilibrium levels of w_j. Indeed, from (22) we see that the regulators will always set marginal access prices below marginal transportation costs in equilibrium.

Cross-border mergers

Cross-border mergers increase the flexibility of the merging parties, in the sense that a merged firm can choose to serve the export market from both *or either* of the exporting countries. Under non-cooperative regulation, this flexibility serves as a credible threat vis-á-vis national regulators. The regulator in country j must now make sure that she offers an access price for the transportation network that discourages the internationally merged firms to re-locate all export production to the other country.

Let $\widehat{\pi}_m(j)$ denote the profits earned by the merged firm m when serving the export market only from country j (given that the other firm uses both plants for export production). Optimal access regulation in the non-cooperative regime must now also satisfy the following *mobility constraint* for each merged firm:

$$\pi_m \geq \widehat{\pi}_m(j). \tag{24}$$

It is straightforward to derive that

$$\widehat{\pi}_m(j) = \frac{((2b+c)a - (c+3b)w_j + bw_{-j})^2 (2b+c)}{2(6b^2 + c^2 + 6bc)^2} - (2 - \theta_c) K - T_j. \tag{25}$$

On the other hand, if the merged firms serve the export market from both countries, equilibrium profits are found by inserting (14) into (12) or (13), and given by

$$\pi_m = \frac{2ca(4b+c)(a - w_A - w_B) + \eta}{2c(6b+c)^2} - (2 - \theta_c) K - T_A - T_B, \tag{26}$$

where

$$\eta := \left(8bc + 18b^2 + c^2\right)\left(w_A^2 + w_B^2\right) - 4bw_Aw_B\left(9b + 2c\right) > 0.$$

Applying the mobility constraints, equilibrium access pricing in the non-cooperative regime with cross-border mergers are given by[8]

$$w_j^c = \frac{abc\left(\alpha\nu + 24b^3\left(3b + 2c\right) - 8c^2b\left(b + c\right) - c^4\right)}{\alpha cb\nu - \left(2b + c\right)\varpi}, \tag{27}$$

$$T_j^c = \frac{ca^2\left(c + 3b\right)^2\gamma\left(6b^2 + c^2 + 6bc\right)^2}{2\left(\alpha cb\nu - \left(2b + c\right)\varpi\right)^2}, \tag{28}$$

where

$$\gamma := c^4 + 14bc^3 + 72b^2c^2 + 160b^3c + 120b^4,$$

$$\nu := c^4 + 12bc^3 + 52b^2c^2 + 102b^3c + 72b^4,$$

$$\varpi := 324b^5 + 612b^4c + 444b^3c^2 + 142b^2c^3 + 20bc^4 + c^5.$$

We can now state our first main result:[9]

Proposition 1 *Under non-cooperative regulation, there exists a critical value $\overline{K}$ such that cross-border mergers yield positive profits in equilibrium if $K < \overline{K}$.*

Unless fixed costs are too high, non-cooperative regulators are not able to extract all rents from internationally merged firms in equilibrium. This is due to the merged firms' ability to play the national regulators out against each other. By credibly threatening to shift export production to a foreign plant, an internationally merged firm can induce each national regulator to offer an access price that in effect will leave the firm with positive profits in equilibrium.[10]

However, the equilibrium outcome given by (27)-(28) is valid only if fixed costs are not too high. If K is above the critical level $\overline{K}$, the regulators can extract all profits in the non-cooperative equilibrium without violating the mobility constraint. In this case, the internationally merged firms do not obtain any strategic advantage from the merger.

[8] Explicit expressions for the mobility constraints are given in Appendix A.

[9] All formal proofs are presented in Appendix C.

[10] We have assumed that merger synergies and fixed costs are independent of whether the merged firms use both plants (see (25)). If the merged firms could save some fixed costs by using only one plant, the national regulators would have to leave even more profits to the firms in order to meet the mobility constraints.

It is easily shown that $\overline{K}$ is increasing in the cost-savings factor θ.[11] Thus, larger merger synergies increase the likelihood of profitable cross-border mergers; not because of the synergies themselves, but because larger synergies make the the threat of production shifting credible for a larger range of K.

When all private profits are not extracted, it also follows that the weight attached to profits in the regulators' objective functions matters for the equilibrium access price. From (27) it is easily confirmed that w_j^c is decreasing in α.

5 Equilibrium market structure

Which is the equilibrium market structure if we allow for all possible two-firm mergers? In order to make predictions about merger formation, we apply the endogenous merger model introduced by Horn and Persson (2001), who treat the merger process as a cooperative game of coalition-formation, where the players are free to communicate and write binding contracts.[12]

To introduce some more notation, let an ownership structure M_k be a partition of the set $\{1, 2, 3, 4\}$ of owners (firms) into coalitions. Allowing only for two-firm mergers, there are 5 possible market structures, comprising a total of 10 different ownership structures. For example, the market structure with two cross-border mergers can be realised through two different ownership structures: $\{1+3, 2+4\}$ and $\{1+4, 2+3\}$. Without going into details about the theoretical foundations of the merger formation model, the approach involves a comparison of any two possible ownership structures M_k and $M_{k'}$, where M_k is said to *dominate* $M_{k'}$ if the combined profits of the *decisive group* of owners are larger in M_k than in $M_{k'}$. The decisive group of owners are the owners that are expected to be able to influence whether M_k will be formed instead of $M_{k'}$, and vice versa. We do not allow side-payments among coalitions, so owners belonging to *identical coalitions* in the two structures cannot affect whether M_k will be formed instead of $M_{k'}$, but all remaining owners can influence this choice and are thus decisive.[13] Finally, the solution

[11] See Appendix C.

[12] Due to the nature of our model, similar results would be obtained in any plausible model of endogenous mergers. Since the decentralised market structure implies zero profits in equilibrium, a merger can never harm non-participating firms. This implies that there are no incentives for 'pre-emptive mergers' in our model.

[13] See Horn and Persson (2001) for a formal definition of *decisive owners*.

concept is the *core*. Those structures that are in the core (i.e., the structures that are undominated) are defined as equilibrium ownership structures. We also impose a strict domination requirement, meaning that the decentralised structure will be preferred to any other ownership structure unless it is *strictly* dominated by such a structure. An ε-cost of merger is sufficient to justify this assumption.

Let us now turn to the solution of the full game. Under *cooperative regulation*, private profits are always fully extracted in equilibrium. Consequently, the decentralised market structure is not strictly dominated by any other market structure, and, consequently, no mergers will take place when regulation is internationally coordinated.

Under *non-cooperative regulation*, on the other hand, we have shown that firms can obtain positive profits by merging cross-border. Thus, if $K < \overline{K}$, the symmetric market structure with two cross-border mergers strictly dominates both the decentralised structure and any market structure involving domestic mergers. However, it is not a priori clear whether a market structure with only a single cross-border merger is dominated by the market structure where all firms merge cross-border. This dominance relation is determined by whether a second cross-border merger is privately profitable. This depends firstly on whether or not access regulation is discriminatory. With discriminatory regulation, it is always possible to extract all profits from the non-merged firms. In this case, a second cross-border merger is always privately profitable. Under non-discriminatory regulation, on the other hand, the non-merged firms benefit from the laxer regulation induced by a single cross-border merger. This free-rider effect may be sufficiently strong to prevent a second merger.

Proposition 2 *(i) Under cooperative regulation, there are no mergers in equilibrium.*

(ii) Under non-cooperative, discriminatory regulation, the equilibrium market structure is two cross-border mergers if $K < \overline{K}$.

(iii) Under non-cooperative, non-discriminatory regulation, if $\theta_c > \widetilde{\theta} \in (0,1)$, *there exists a critical value* $\widetilde{K} < \overline{K}$ *such that the equilibrium market structure is two cross-border mergers if* $K \in \left(\widetilde{K}, \overline{K}\right)$.

Part (iii) of the Proposition basically states that, with non-discriminatory regulation, private profitability of a second cross-border merger requires a certain amount of merger synergies. Otherwise, the aggressive response of the already merged firm will make a second merger unprofitable, as in a 'standard' Cournot homogenous goods oligopoly.

6 Social welfare

In this section we discuss two interrelated questions regarding social welfare. First, which types of merger, if any at all, are preferred from a welfare point-of-view? Second, assuming that merger decisions are endogenously made, is international harmonisation of access regulation socially desirable? For the first question, we restrict attention to symmetric market structures.

In the *cooperative* regulation regime, a social ranking of market structures is straightforward. In any market structure, the regulatory parameters are set so that total industry rents are maximised. Then the following result is trivially established:

Proposition 3 *Under cooperative regulation, any mergers are socially desirable if they yield some cost synergies. The socially most preferable market structure is the one in which the largest merger synergies are realised.*

In the *non-cooperative* regulation regime, things are far less straightforward. However, by comparing the different equilibrium welfare expressions reported in Appendix B, we can establish the following results:

Proposition 4 *Assume that regulation is non-cooperative.*

(i) Compared with the decentralised structure, domestic mergers are always welfare improving, while cross-border mergers are welfare improving if α or K is sufficiently high.

(ii) Comparing domestic and cross-border mergers, and assuming that cost synergies are identical in both types of merger, cross-border mergers are always socially preferred if α is sufficiently high, while domestic mergers are preferred if α and K are sufficiently low.

Due to the rent-generating effect of a more concentrated market structure, domestic mergers are always welfare improving, even in the absence of cost synergies. On the other hand, if firms merge cross-border, all pure profits cannot be extracted by the regulators. Consequently, the welfare effect of cross-border mergers depends on how private profits are evaluated. If α is sufficiently high, there is a low social cost of leaving pure profits in the hands of the firms, and cross-border mergers are always welfare improving (relative to no mergers). In general, though, the welfare loss of not being able to extract all rents must be weighed against the merger-induced increase in total rents. Thus, for low levels of α it takes a sufficiently high level of K to make cross-border mergers welfare improving.

Finally, the welfare ranking of *domestic versus cross-border* mergers follows much the same logic. If both types of merger are equal in terms of cost synergies, i.e., $\theta_d = \theta_c$, cross-border mergers are preferred when α is sufficiently high. Consider the limit $\alpha \to 1$. In this case, there is no welfare cost of leaving positive profits in equilibrium and the welfare ranking is fully explained by the effect of different types of merger on national regulators' rent-shifting incentives. With domestic mergers, rent-shifting incentives cause regulators to set marginal access prices below marginal transportation costs, which reduces total industry rents. With cross-border mergers, on the other hand, the Prisoners' Dilemma characteristics of the non-cooperative equilibrium are less pronounced, since the negative externality between domestic plants (which are owned by different firms) counteracts the national regulators' rent-shifting incentives. This contributes to higher total industry profits in equilibrium, compared with the case of domestic mergers.

The arguments in this subsection make it clear that the results regarding welfare comparisons are general, and not dependent on the particular functional forms used in the analysis. The main reason for employing those special functional forms is to facilitate the analysis in the next subsection, where one needs to examine whether it can be the case that cross-border mergers are welfare improving (due to, say, large fixed costs K) and at the same time leave rents to firms (which requires that fixed costs cannot be too large).

6.1 Is international policy coordination beneficial?

Let us now turn to the question of whether or not international harmonisation of access regulation is desirable. The basic idea here is that different policy regimes might imply different market structures in equilibrium. Assume that the countries can commit to a particular policy regime at the outset of the game, before firms make their merger decisions. In this case, we know that no mergers will be undertaken if regulation is transnationally coordinated. If regulation policies are *not* coordinated, however, there may be incentives for cross-border mergers. We consider the case where the equilibrium market structure is two cross-border mergers under non-cooperative regulation. From Proposition 2, we know that this amounts to assuming either that regulation is discriminatory and $K < \overline{K}$, or that $\widetilde{K} < K < \overline{K}$.

In this case, the question of whether or not to coordinate regulation policies across borders introduces the following trade-off. Non-cooperative regulation implies that national regulators engage in a Prisoners' Dilemma type of policy game, due to the incentives for

using access prices as instruments for strategic trade policy purposes. These incentives are eradicated by international harmonisation. On the other hand, such harmonisation will remove private incentives for potentially welfare improving mergers. An evaluation of this trade-off reduces to a comparison of welfare in the non-cooperative regulation regime with cross-border mergers and the cooperative regime without mergers.

Proposition 5 *If $\theta_c > \theta^* \in (0,1)$, there exists a critical value $K^* < \overline{K}$ such that international coordination of regulation policies is not beneficial for $K \in \left(K^*, \overline{K}\right)$.*

In light of the welfare trade-off outlined above, the intuition behind this result is straightforward. If merger synergies – in absolute terms – are sufficiently high, the social benefit of inducing welfare improving mergers outweigh the cost of the negative externalities suffered in a non-harmonised regulation regime. On the other hand K cannot be too large, because then the threat of shifting production between the plants in an internationally merged firm is not effective.

The relative magnitudes of the different regimes can be illustrated by considering a specific numerical example. Assume that $a = 10$, $b = c = 1$, and $\alpha = 0.8$. This yields $\theta^* = 0.38$. Thus, for any $\theta > 0.38$ there is a possibility that international policy coordination is not beneficial. Now assume that $\theta = 0.8$. In this case, we have that $K^* = 2.73$ and $\overline{K} = 5.47$, implying that policy coordination is not beneficial if $K \in (2.73, 5.47)$. In this example and for $K = 5$ policy coordination yields welfare $W_j = 1.11$ while non-coordination yields welfare $W_j^c = 3.47$, implying that the latter alternative allows a significant fraction of potential cost savings ($\theta K = 4$) to be realised and reflected in improved welfare.

7 Concluding remarks

In many industries national regulators try to regulate the activities of firms that are active in international markets. Could this imply that firms choose international mergers over domestic ones, because this gives an opportunity to pit national regulators against each other – even if a domestic merger would have been better at realising merger synergies? Would this in turn imply that international policy coordination is called for?

We have sought to answer these questions within the framework of a model of access regulation. There are two producers in each of two countries, all producing for consump-

tion in a third-country market. This third market can only be reached by a transportation network where national regulators set the access price. The access price has a two-part nature with a per-unit price and a lump-sum fee. Regulation takes place under full information. International cooperative regulation will then confiscate all profit from the firms and maximise joint cartel profit. The problem is that no mergers will take place regardless of the size of possible merger synergies, precisely because all profits from this would be confiscated in the end. Under non-cooperative regulation, a firm's only chance to rescue some profits is to merge internationally. The power of the one national regulator is then weakened by the threat that the firm could move production to the jurisdiction of the other national regulator. We show that lack of policy coordination can actually be welfare improving: True, some profits are left in the hands of the firms, but on the upside, some merger synergies are actually realised.

We have chosen the access regulation framework because we think it can be descriptive of some important real markets, such as gas and electricity markets, but also because it lends to a relatively simple statement of our main findings. We do think, however, that the main logic behind our results will be mirrored in many other regulation situations, where production and regulation in one country is linked to what happens in another regulated economy, on the market side or the cost side. Take, for example, environmental regulation. Assume that polluting firms that produce for a world market must pay environmental taxes in order to be allowed to operate. The 'licence to operate' can be seen as the provision of 'access'. Clearly, an international merger would in such a setting give rise to much the same opportunities to play domestic regulators out against each other as in the present model. Regulation theory has come a long way the last two decades, and even multi-principal regulation is by now a relatively large research topic. We nevertheless think that questions about how multi-principal regulation influences merger activity and what this in turn signifies for regulatory policy are underresearched – and the present quite simple model is just a first attack on this kind of questions.

A Mobility constraints under non-cooperative regulation

Consider the case of two cross-border mergers. Using (25) and (26) from Section 4, the mobility constraints for national regulators can be expressed as

$$T_A \leq \frac{(ac-(c+3b)\,w_A+3bw_B)\,(\gamma ac-\beta w_A+\phi bw_B)}{2c\,(6b+c)^2\,(6b^2+c^2+6bc)^2}, \tag{A.1}$$

$$T_B \leq \frac{(ac-(c+3b)\,w_B+3bw_A)\,(\gamma ac-\beta w_B+\phi bw_A)}{2c\,(6b+c)^2\,(6b^2+c^2+6bc)^2}, \tag{A.2}$$

where

$$\beta := c^5+17bc^4+110b^2c^3+328b^3c^2+432b^4c+216b^5,$$

$$\phi := 3c^4+38bc^3+168b^2c^2+312b^3c+216b^4,$$

and γ is defined in Section 4. By using (A.1)-(A.2) in the regulators' maximisation problems, we derive (27) and (28), given in Section 4.

B Social welfare in the symmetric market structure equilibria

Using the equilibrium access prices derived in the main body of the paper, equilibrium expressions for social welfare in the symmetric market structures, under the two different regulatory regimes, are given as follows.

B.1 Coordinated regulation

No mergers:

$$W_j = \frac{a^2}{8b+c} - 2K. \tag{B.1}$$

Domestic mergers:

$$W_j^d = \frac{a^2}{8b+c} - (2-\theta_d)\,K. \tag{B.2}$$

Cross-border mergers:

$$W_j^c = \frac{a^2}{8b+c} - (2-\theta_c)\,K. \tag{B.3}$$

B.2 Non-cooperative regulation

No mergers:

$$W_j = \frac{\left(7bc + 4b^2 + c^2\right)(3b + c)\, a^2}{(7b + c)^2 (2b + c)^2} - 2K. \tag{B.4}$$

Domestic mergers:

$$W_j^d = \frac{\left(8bc + 8b^2 + c^2\right)(4b + c)\, a^2}{\left(10bc + 20b^2 + c^2\right)^2} - (2 - \theta_d)\, K. \tag{B.5}$$

Cross-border mergers:

$$W_j^c = \frac{a^2 (c + 3b)\left(6b^2 + c^2 + 6bc\right)^2 \left(c\chi + 12\alpha b^3 (4b + 3c)\left(9b^2 + 6bc + 2c^2\right)\right)}{\left(\alpha cb\nu - (2b + c)\, \varpi\right)^2} - \alpha (2 - \theta_c)\, K, \tag{B.6}$$

where

$$\chi := c^5 + 19bc^4 + 6c^3\alpha b^2 + 130b^2c^3 + 392b^3c^2 + 504b^4c + 216b^5$$

and ν and ϖ have been defined in Section 4.

C Proofs

All proofs require only quite straightforward algebra. However, some of the algebra is extremely tedious and thus omitted. In these cases, we only provide a main sketch of the proof.[14]

C.1 Proof of Proposition 1

Inserting the equilibrium access price, (27)-(28), into (26), equilibrium profits for an internationally merged firm m, under non-cooperative regulation, is given by

$$\pi_m^c = \frac{2a^2 b\nu (c + 3b)^2 \left(6b^2 + c^2 + 6bc\right)^2}{\left(\alpha cb\nu - (2b + c)\, \varpi\right)^2} - (2 - \theta_c)\, K, \tag{C.1}$$

where ν and ϖ are defined in Section 4. It follows straightforwardly that $\pi_m^c > 0$ if $K < \overline{K}$, where

$$\overline{K} := \frac{2a^2 b\nu (c + 3b)^2 \left(6b^2 + c^2 + 6bc\right)^2}{(2 - \theta_c)\left(\alpha cb\nu - (2b + c)\, \varpi\right)^2}. \tag{C.2}$$

For $K > \overline{K}$, all profits are extracted through the fixed fees in equilibrium. ■

[14] The 'nitty gritty' of the calculations are available from the authors upon request.

C.2 Proof of Proposition 2

Given our assumptions about merger formation, parts (i) and (ii) of the Proposition follow immediately from the analysis of Sections 3 and 4. To prove part (iii) of the Proposition, we need to derive the equilibrium with a single cross-border merger. Assume that firms 1 and 3 merge. If the merged firms supply the good from both countries, profits are given by

$$\pi_{1+3} = \frac{2ac\left(4b+c\right)\left(c+b\right)^2\left(a-w_A-w_B\right)+\left(c+2b\right)\delta\left(w_A^2+w_B^2\right)-4b\xi w_A w_B}{2c\left(c^2+7cb+8b^2\right)^2} - \left(2-\theta_c\right)K - T_A - T_B, \tag{C.3}$$

where

$$\delta := c^3+8bc^2+21b^2c+16b^3,$$

$$\xi := 14bc^2+27b^2c+2c^3+16b^3,$$

Profits of the non-participating firms are given by

$$\pi_2 = \frac{\left(c+2b\right)\left(a\left(c+b\right)\left(c+2b\right)-w_A\left(c^2+5b\left(c+b\right)\right)+bw_B\left(2c+3b\right)\right)^2}{2\left(c+b\right)^2\left(c^2+7cb+8b^2\right)^2} - K - T_A, \tag{C.4}$$

$$\pi_4 = \frac{\left(c+2b\right)\left(a\left(c+b\right)\left(c+2b\right)-w_B\left(c^2+5b\left(c+b\right)\right)+bw_A\left(2c+3b\right)\right)^2}{2\left(c+b\right)^2\left(c^2+7cb+8b^2\right)^2} - K - T_B. \tag{C.5}$$

On the other hand, if the merged firm chooses to supply the good only from country j, it will realise a profit of

$$\widehat{\pi}_{1+3}\left(j\right) = \frac{\left(2b+c\right)\left(a\left(c+b\right)-w_j\left(c+2b\right)+w_{-j}b\right)^2}{2\left(c+b\right)^2\left(c+4b\right)^2} - \left(2-\theta_c\right)K - T_j. \tag{C.6}$$

Imposing the mobility conditions $\pi_{1+3} \geq \widehat{\pi}_{1+3}\left(j\right)$, equilibrium access regulation is characterised by

$$w_j = \frac{abc\rho}{\psi}, \tag{C.7}$$

$$T_j = \frac{\vartheta^2\left(64b^4+102b^3c+53c^2b^2+12c^3b+c^4\right)\left(4b+c\right)^2a^2c}{2\psi^2}, \tag{C.8}$$

where

$$\begin{aligned}\psi \quad : \quad &= 2c^6\alpha b + 25c^5\alpha b^2 + 123c^4\alpha b^3 + 305c^3\alpha b^4 + 360c^2\alpha b^5 + 160c\alpha b^6 - 2c^7 \\ &-43c^6 b - 355c^5 b^2 - 1472c^4 b^3 - 3312b^4 c^3 - 4000b^5 c^2 - 2368b^6 c - 512b^7,\end{aligned}$$

$$\begin{aligned}\rho \quad : \quad &= 2c^5\alpha + 25\alpha b c^4 + 123\alpha b^2 c^3 + 305\alpha b^3 c^2 + 360\alpha b^4 c \\ &+160b^5\alpha - 3c^5 - 32bc^4 - 121b^2 c^3 - 196b^3 c^2 - 112b^4 c,\end{aligned}$$

$$\vartheta := 2c^3 + 10bc^2 + 13b^2 c + 4b^3.$$

Equilibrium profits are given by

$$\pi_{1+3} = \frac{(c+2b)\,(c+4b)^2\left(c^2+7cb+8b^2\right)^2\vartheta^2 a^2}{2\psi^2} - (2-\theta_c)\,K, \tag{C.9}$$

$$\pi_2 = \pi_4 = \frac{(c+4b)^2\,\vartheta^2 b\left(2c^4+23c^3 b+98c^2 b^2+192cb^3+128b^4\right)a^2}{2\psi^2} - K. \tag{C.10}$$

The profitability of a second cross-border merger, i.e., a merger between firms 2 and 4, are determined by a comparison of (C.1) and (C.10). It turns out that a second merger is profitable if $K > \widetilde{K}$, where

$$\widetilde{K} := \frac{2F}{\theta_c}, \tag{C.11}$$

where

$$F := \frac{a^2 b^2\,(A+B)}{2\Lambda^2\Upsilon^2},$$

$$\begin{aligned}\Lambda \quad : \quad &= -\alpha c^5 b - 12\alpha c^4 b^2 - 52\alpha c^3 b^3 - 102\alpha c^2 b^4 - 72\alpha c b^5 + 648b^6 + 1548b^5 c \\ &+1500b^4 c^2 + 728b^3 c^3 + 182b^2 c^4 + 22bc^5 + c^6,\end{aligned}$$

$$\begin{aligned}\Upsilon \quad : \quad &= -2c^6\alpha b - 25c^5\alpha b^2 - 123c^4\alpha b^3 - 305c^3\alpha b^4 - 360c^2\alpha b^5 - 160c\alpha b^6 + 2c^7 \\ &+43bc^6 + 355b^2 c^5 + 1472b^3 c^4 + 3312b^4 c^3 + 4000b^5 c^2 + 2368b^6 c + 512b^7,\end{aligned}$$

and $A > 0$ and $B > 0$ are functions of the parameters c, b and α.[15,16]

[15] $A := 1735\,729\,742\,848b^{17}c^6\alpha + 120\,415\,319\,936b^{11}c^{12}\alpha + 1935\,533\,861\,120b^{16}c^7\alpha + 213\,362\,933\,760b^{20}c^3\alpha + 1194\,520\,307\,712b^{18}c^5\alpha + 1699\,171\,258\,048b^{15}c^8\alpha + 896\,007\,057\,408b^{19}c^4 + 4c^{23} + 1528\,823\,808b^{23} + 368\,730\,048\,704b^{12}c^{11} + 134\,842\,288b^6 c^{17} + 328\,550\,296b^7 c^{16}\alpha + 540b^2 c^{21}\alpha + 16\,848b^3 c^{20}\alpha + 19\,619\,905\,536b^{22}c + 254bc^{22} + 54\,584\,646\,208b^{10}c^{13} + 324\,576b^4 c^{19}\alpha + 8bc^{22}\alpha + 9569\,185\,592b^9 c^{14}\alpha + 4586\,471\,424b^{22}c\alpha + 1978\,929\,564b^8 c^{15}\alpha + 680\,525\,003\,824b^{13}c^{10}\alpha + 1261\,102\,331\,120b^{14}c^9 + 4344\,742b^5 c^{18}\alpha + 46\,140\,751\,872b^{21}c^2\alpha > 0$

[16] $B := 6b^3 c^{20}\left(23\,411 - 107\alpha^2\right) + 3072b^{18}c^5\left(499\,195\,156 - 23\,906\,873\alpha^2\right) +$

It follows that the market structure with two cross-border mergers dominates all other market structures if $K \in \left(\widetilde{K}, \overline{K}\right)$. It remains to establish when $\widetilde{K} < \overline{K}$, if at all. We see that $\partial\widetilde{K}/\partial\theta_c < 0$ while $\partial\overline{K}/\partial\theta_c > 0$, implying that $\partial\left(\overline{K} - \widetilde{K}\right)/\partial\theta_c > 0$. From (C.2) and (C.11), it is immediately clear that $\lim_{\theta_c \to 0}\left(\overline{K} - \widetilde{K}\right) < 0$. It is also relatively straightforward to show that $\lim_{\theta_c \to 1}\left(\overline{K} - \widetilde{K}\right) > 0$.[17] Thus, there exists a critical value $\widetilde{\theta} \in (0,1)$, such that $\overline{K} > \widetilde{K}$ if $\theta_c > \widetilde{\theta}$.■

C.3 Proof of Proposition 4

(i) Comparing (B.4) and (B.5), the market structure with two *domestic* mergers yields higher welfare than the decentralised structure if

$$\frac{16b^4\left(92b^3 + c^3 + 69b^2c + 15bc^2\right)a^2}{(7b+c)^2\left(10bc + 20b^2 + c^2\right)^2(2b+c)^2} + \theta_d K > 0. \tag{C.12}$$

We see that this is always true. Comparing (B.4) and (B.6), the market structure with two *cross-border* mergers yield higher welfare than the decentralised structure if

$$-a^2(c+3b)\,b\left(\frac{\Psi(2b+c)^2 + \alpha\nu\left(\alpha c^2 b\left(7bc + 4b^2 + c^2\right)\nu - 2(2b+c)\vartheta\right)}{(\alpha cb\nu - (2b+c)\varpi)^2(7b+c)^2(2b+c)^2}\right) + (2(1-\alpha) + \alpha\theta_c)K > 0, \tag{C.13}$$

where

$$\begin{aligned}\Psi \;:\; &= 2c^{11} + 79c^{10}b + 1377c^9b^2 + 14\,010c^8b^3 + 92\,616c^7b^4 \\ &+417\,892c^6b^5 + 1310\,220c^5b^6 + 2837\,016c^4b^7 \\ &+4117\,104c^3b^8 + 3770\,064c^2b^9 + 1940\,112cb^{10} + 419\,904b^{11},\end{aligned}$$

$$\begin{aligned}\vartheta \;:\; &= 10\,584b^8 + 30\,780b^7c + 37\,188b^6c^2 + 24\,564b^5c^3 \\ &+9874b^4c^4 + 2469b^3c^5 + 370b^2c^6 + 30bc^7 + c^8,\end{aligned}$$

$64b^{17}c^6\left(31\,517\,155\,826 - 1861\,535\,989\alpha^2\right) + 32b^{15}c^8\left(56\,001\,585\,723 - 4105\,657\,918\alpha^2\right) +$
$442\,368b^{20}c^3\left(867\,485 - 18\,823\alpha^2\right) + 12b^2c^{21}\left(630 - \alpha^2\right) + 30c^{18}b^5\left(594\,090 - 8471\alpha^2\right) +$
$2654\,208b^{21}c^2\left(42\,209 - 386\alpha^2\right) + 24b^{10}c^{13}\alpha\left(1564\,843\,467 - 123\,681\,643\alpha\right) +$
$16b^{11}c^{12}\left(9657\,055\,901 - 604\,759\,269\alpha^2\right) + 96b^{13}c^{10}\left(7738\,786\,193 - 571\,981\,103\alpha^2\right) +$
$2b^7c^{16}\left(407\,051\,276 - 11\,529\,975\alpha^2\right) + 73\,728b^{19}c^4\alpha\left(8229\,019 - 426\,466\alpha\right) +$
$2b^9c^{14}\left(8091\,477\,332 - 368\,224\,931\alpha^2\right) + b^4c^{19}\left(1830\,547 - 16\,152\alpha^2\right) + 40b^8c^{15}\left(99\,927\,847 - 3663\,841\alpha^2\right) +$
$496b^{16}c^7\left(4249\,438\,476 - 287\,942\,005\alpha^2\right) + b^6c^{17}\alpha\left(43\,062\,848 - 2804\,169\alpha\right) +$
$16b^{12}c^{11}\alpha\left(19\,769\,962\,473 - 1599\,851\,626\alpha\right) + 96b^{14}c^9\alpha\left(12\,444\,704\,779 - 989\,888\,295\alpha\right) > 0$

[17] The details of the calculations, which requires some very tedious, but straightforward, algebra, are available from the authors upon request.

and ν and ϖ are defined before. It is easily shown that the first term in (C.13) is monotonically increasing in α, and positive (negative) for $\alpha = 1$ ($\alpha = 0$). Thus, since the second term is non-negative, the inequality in (C.13) holds if α is sufficiently high. If α is sufficiently low, so that the first term is negative, K must be sufficiently high to make the inequality hold. The highest value K is allowed to take in this expression is $\overline{K}$. It is easily verified that the inequality holds for $\alpha = 0$ and $K = \overline{K}$. It follows that a sufficiently high value of K (within the relevant range) is always enough to make the inequality in (C.13) hold.

(ii) Comparing (B.5) and (B.6), domestic mergers are preferred to cross-border mergers, from a welfare-point-of-view, if

$$a^2 b \frac{\Phi + \alpha\nu\left(\alpha c^2 b\left(4b+c\right)\left(8bc+8b^2+c^2\right)\nu - \Omega\right)}{\left(10bc+20b^2+c^2\right)^2\left(\alpha cb\nu - \left(2b+c\right)\varpi\right)^2} - K\left(2-\theta_d-\alpha\left(2-\theta_c\right)\right) > 0, \quad \text{(C.14)}$$

where

$$\begin{aligned}\Omega \;:\; &= 2c^{10} + 74bc^9 + 1182b^2c^8 + 1180\,032b^7c^3 + 1364\,832b^8c^2 + 905\,472b^9c \\ &+259\,200b^{10} + 10\,792b^3c^7 + 62\,816b^4c^6 + 245\,376b^5c^5 + 654\,968b^6c^4,\end{aligned}$$

$$\begin{aligned}\Phi \;:\; &= 28\,452c^{11}b^3 + 28\,301\,024b^7c^7 + 231\,221\,376b^{10}c^4 + 256\,016b^4c^{10} \\ &+171\,300\,096b^{12}c^2 + 7883\,368b^6c^8 + 155\,414\,640b^9c^5 + 2138b^2c^{12} \\ &+1651\,276b^5c^9 + 97bc^{13} + 71\,663\,616b^{13}c + 243\,694\,656b^{11}c^3 \\ &+76\,655\,168b^8c^6 + 13\,436\,928b^{14} + 2c^{14}.\end{aligned}$$

Setting $\theta_d = \theta_c$, the second term in (C.14) is always non-negative. The first term in (C.14) is monotonically decreasing in α, and positive (negative) for $\alpha = 0$ ($\alpha = 1$). Thus, the inequality never holds when α is sufficiently high. When α is sufficiently low, the sign of the expression is a priori ambiguous. A higher value of K will reduce the likelihood that the inequality holds. Inserting the extreme value in the upper limit of the relevant range, $K = \overline{K}$, it is easily shown that the expression in (C.14) is negative. Thus, even for $\alpha = 0$, the inequality holds only if K is sufficiently low.■

C.4 Proof of Proposition 5

Comparing (B.1) and (B.6), we find that harmonisation is not preferred if $K > K^*$, where

$$K^* := \frac{a^2 b\left(\Theta + \alpha\nu\left(\alpha c^2 b\nu - \sigma\right)\right)}{\left(2\left(1-\alpha\right)+\alpha\theta_c\right)\left(8b+c\right)\left(\alpha cb\nu - \left(2b+c\right)\varpi\right)^2}, \quad \text{(C.15)}$$

where

$$\begin{aligned}\sigma \;\; : \;\; &= 2c^7 + 50bc^6 + 502b^2c^5 + 2680b^3c^4 + 8328b^4c^3 \\ &+14\,976b^5c^2 + 14\,040b^6c + 5184b^7,\end{aligned}$$

$$\begin{aligned}\Theta \;\; : \;\; &= 77c^{10}b + 2605\,104c^4b^7 + 3750\,624c^3b^8 + 419\,904b^{11} + 2c^{11} \\ &+1819\,584cb^{10} + 3446\,064c^2b^9 + 13\,264c^8b^3 + 87\,128c^7b^4 \\ &+1215\,672c^5b^6 + 1318c^9b^2 + 390\,892c^6b^5.\end{aligned}$$

This case is only relevant if $K^* < \overline{K}$. From (C.2) and (C.15) we have that

$$\overline{K} - K^* = a^2 b \frac{-2by^2 + \theta_c\left(u + \alpha cb\nu\tau\right)}{\left(2-\theta_c\right)z^2\left(2\left(1-\alpha\right)+\alpha\theta_c\right)\left(8b+c\right)}, \tag{C.16}$$

where

$$\begin{aligned}y \;\; : \;\; &= c^5\alpha + 12c^4\alpha b + 52c^3\alpha b^2 + 102c^2\alpha b^3 + 72c\alpha b^4 + c^5 \\ &+22bc^4 + 160b^2c^3 + 480b^3c^2 + 576b^4c + 216b^5,\end{aligned}$$

$$\begin{aligned}u \;\; : \;\; &= 77c^{10}b + 2605\,104c^4b^7 + 3750\,624c^3b^8 + 419\,904b^{11} \\ &+2c^{11} + 1819\,584cb^{10} + 3446\,064c^2b^9 + 13\,264c^8b^3 \\ &+87\,128c^7b^4 + 1215\,672c^5b^6 + 1318c^9b^2 + 390\,892c^6b^5,\end{aligned}$$

$$\begin{aligned}\tau \;\; : \;\; &= 2c^5 + c^5\alpha + 12c^4\alpha b + 44bc^4 + 52c^3\alpha b^2 + 320b^2c^3 \\ &+102c^2\alpha b^3 + 960b^3c^2 + 72c\alpha b^4 + 1152b^4c + 432b^5,\end{aligned}$$

$$\begin{aligned}z \;\; : \;\; &= -\alpha c^5 b - 12\alpha c^4 b^2 - 52\alpha c^3 b^3 - 102\alpha c^2 b^4 - 72\alpha cb^5 + 648b^6 \\ &+1548b^5c + 1500b^4c^2 + 728b^3c^3 + 182b^2c^4 + 22bc^5 + c^6.\end{aligned}$$

It can be shown that $\left(\overline{K} - K^*\right)$ is monotonically increasing in θ, and $\overline{K} - K^* < 0$ if $\theta = 0$. It is also easily confirmed that $\lim_{\theta\to 1}\left(\overline{K} - K^*\right) > 0$. This implies that $K^* < \overline{K}$ if θ is above a critical level $\theta^* < 1$. From (C.16) we derive

$$\theta^* = \frac{2by^2}{u + \alpha cb\nu\tau}. \tag{C.17}$$

It can also be shown that $\widetilde{K} < K^* < \overline{K}$ for $\theta > \theta^*$. ■

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